PB83-253740

Assessment of Discharges from Sasol I Lurgi-Based Coal Gasification Plant

Fluor Engineers and Constructors, Inc.
Irvine, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Aug 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/7-83-044	2.	3. RECIPIENT'S ACCESSION NO. PB83 253740
4. TITLE AND SUBTITLE Assessment of Discharges from Sasol I Lurgi-based Coal Gasification Plant		5. REPORT DATE August 1983 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) S.J. Thomason, G. Kasper, J.F. Nagy, A. Tzou, and L.S. Pernot		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Fluor Engineers and Constructors, Inc. 2801 Kelvin Avenue Irvine, California 92730		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-3691
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 9/81 - 3/82 14. SPONSORING AGENCY CODE EPA/600/13
15. SUPPLEMENTARY NOTES IERL-RTP project officer is William J. Rhodes, Mail Drop 61, 919/541-2853.		

16. ABSTRACT The report discusses analytical information, obtained from Sasol I, on the emission and effluent streams analyzed in the normal course of operation and testing. The purpose was to provide EPA with representative information on a commercial-size Lurgi-based coal gasification project. The final report gives operating data and supplementary data, including material balances and pollutant distribution evaluations. Although much of this supplementary information is based on engineering estimates and calculations, it is believed to be representative of a Sasol I gasification operation. Findings include: about 89% of the sulfur in the feed coal was in the gas streams, and 4% in the liquid streams; emissions of non-methane hydrocarbons from process vent streams were minimal, compared to combustion emissions from coal fired boilers; and most of the trace metals in the feed coal remained in the ash and had a low solubility in water (arsenic was the exception: its solubility in water and resultant leachability from the ash may require additional study). The data presented should be confirmed by a series of test runs before they are used for process design purposes, cost estimates, or environmental control studies.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Coal Gasification	Stationary Sources	13H
Sulfur	Lurgi	07B
Hydrocarbons	Sasol I	07C
Chemical Analysis	Trace Metals	07D

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	37
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB83-253740

EPA-600/7-83-044
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Washington, DC 20460

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

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ABSTRACT

This final report provides Sasol I plant operating and emission data for the Lurgi coal gasification operation. These data are presented in two distinct sections, Phase I and Phase II.

The Phase I section presents the commercial plant data provided to Fluor by Sasol. These data include various stream flow rates and compositions; however, they are incomplete and do not define the ultimate disposition of pollutants emitted throughout the process. In addition, process descriptions are provided for the various units involved in the coal conversion process.

The Phase II section supplements the Phase I data with material balances and pollutant distribution evaluations which are based largely on engineering estimates and calculations by Fluor. The sulfur balance and sulfur distribution performed indicate that about 89 percent of the total sulfur contained in the feed coal will be present in the gas streams, 4 percent will be present in the liquid streams, and 7 percent will concentrate in the ash.

Most of the trace metals originally present in the feed coal have low water solubilities and high boiling points and, therefore, concentrate in the gasifier ash.

The data in this report are adequate for quick reviews or preliminary environmental considerations. However, if the data were to be used more rigorously; e.g., detailed designs or environmental promulgations, they should first be confirmed by actual test runs.

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1.0 INTRODUCTION

Since 1955, South Africa has operated an oil-from-coal plant known as Sasol, an acronym for South Africa Coal, Oil, and Gas Corporation. Sasol I* (located at Sasolburg, Orange Free State, Republic of South Africa) converts 6 million metric tons (6.6 million tons) of coal per year to produce motor fuels, LPG, petrochemicals, and pipeline gas.

Sasol I utilizes Lurgi dry ash gasifiers using steam and oxygen with low grade, high ash coal. The coal is gasified to produce a snythesis gas containing a variety of constitutents (e.g., methane, hydrogen, carbon monoxide, carbon dioxide, ammonia, hydrogen sulfide, and steam). The crude synthesis gas from the Lurgi gasifiers is cooled for particulate and condensate removal and fed to a gas purification unit where it is scrubbed with cold methanol to remove sulfur compounds, carbon dioxide, and other unwanted components. The synthesis gas needs this purification to protect downstream catalysts. The purified synthesis gas is sent to Fischer-Tropsch synthesis. Fischer-Tropsch synthesis is the combination of hydrogen and carbon monoxide with the aid of an iron catalyst to produce a range of hydrocarbons including motor fuels.

Two Fischer-Tropsch synthesis processes are used as Sasol I: The German developed process, Arge, with pelletized catalyst packed in a tubular, fixed-bed reactor, as well as the American concept developed by Sasol and called Synthol, in which the powdered catalyst is swept along by the gas stream in a circulating fluid-bed reactor system. The first process produces mainly higher boiling point materials consisting of waxes, some oils with medium boiling point such as diesel oils, and smaller amounts of gasoline, liquefied petroleum gas, and chemicals. In contrast, the second process produces mainly low boiling point materials such as liquefied petroleum gas and gasoline as well as a considerable amount of chemicals such as alcohol and acetone. The unique combination of the two processes yields virtually the full range of products normally derived from crude oil in addition to a number of others usually manufactured in petrochemical plants. Sasol I is also a major supplier of industrial gas via a high-pressure pipeline to South Africa's industrial areas.

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* Sasol I, rather than Sasol's official terminology of Sasol One, has been used throughout the report.

This report consists of two parts, Phase I and Phase II. Phase I provides a plant description and deals with the specific emission data furnished by the Sasol I Plant. However, the environmental data presented in Phase I are not sufficient to allow closure on a material balance for pollutants. In Phase II, the missing data are provided through best engineering estimates based on calculations and projection of published and nonproprietary data from other sources. The estimated data supplement the Phase I data enabling a material balance to be performed for the overall gasification plant and on pollutants such as sulfur and selected trace elements.

Discussions on the background of the material balance, distribution of sulfur and trace elements, and emissions of hydrocarbons are presented in this report. It is recommended that prior to more rigorous use of this information, test runs at the commercial plant be performed in order to verify the estimated data. However, the cost effectiveness of such test runs should be considered in relation to potential savings achievable by closer design specifications for environmental control systems units such as the sulfur recovery unit.

This report addresses emissions from the gasifier unit, acid gases from the Rectisol unit, depressurization gases from the tar separation process, Phenosolvan wastewater, sulfur recovery unit discharges, and the trace elements found in tar and oil as well as the prepared coal and dry ash. Available plant data on streams of major environmental interest for the above topics are numbered on Figure 1 and shown in Tables 1, 2, and 3. Additional calculations were made establishing data on streams numbered on Figure 2 and shown in Tables 4 through 9. Absence of data in the tables does not indicate that constitutents were not present, but rather that results were not reported.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 Phase I

The Phase I section presents in Tables 1, 2, and 3 the commercial plant data provided to Fluor by Sasol. A cursory review of these data reveals critical gaps in flow rates and compositions which preclude determining from these data alone the final disposition of pollutants emitted throughout the process.

The reported data, however, provided a foundation of information from which a more complete definition of pollutant disposition could be established. This was achieved in Phase II by providing the missing data through calculations, projections of nonpropietary data from other sources, and engineering estimates.

This approach was taken because the alternative of obtaining complete data from a test run at the commercial plant would be considerably more costly and time-consuming. In addition, an engineering estimate should also be useful in designing a test program if such a program were later found to be necessary.

2.2 Phase II

The Phase II section includes engineering estimates supplementing Phase I data from Sasol in regard to material balances and pollutant distribution. These engineering estimates adequately represent the Lurgi type coal gasification process at Sasol I.

It is concluded that:

- Approximately 89 percent of the sulfur goes to the gas phase, 7 percent to the ash, and 4 percent to the liquid stream.
- Of the sulfur going to the liquid and gas streams, most can be prevented from release to the atmosphere by conventional means such as by use of naphtha desulfurization and of the sulfur recovery unit (99 percent H_2S removal).
- Most of the trace metals addressed were concentrated in the gasifier ash and have a low solubility in water. Arsenic, however, because of its solubility in water results in a major portion in the water phase and presents a potential leaching problem for the ash going to disposal.

Cadmium oxide solubility enhancement by the presence of ammonium salts could be studied to see if it accounts for the higher than expected cadmium concentrations in the aqueous phase.

These estimates are for preliminary use in the design of test programs. If these data were to be used more rigorously; e.g., detailed designs or environmental promulgations, they should first be confirmed by actual test runs.

3.0 PLANT DESCRIPTION (Phase I)

3.1 Coal Preparation

Coal is sent to underground primary crushers by conveyors prior to being transported to a live storage pile. Conveyors then transfer the coal to secondary crushers where the coal is further reduced in size.

The final product of the crushing operation consists of two coal sizes which are separated into fines and those sizes suitable for feed to the Lurgi gasifiers. Coal on the conveyors is intermittently sprayed with water to control dust. The fines are sent to the power plant where they are used for power and steam production.

3.2 Oxygen and Steam Production

The oxygen used in the Sasol I plant is produced by air separation. In order to separate oxygen and nitrogen, air is compressed and cooled to a temperature of approximately 119K (-310°F). Oxygen is used in the Lurgi gasifiers as well as in the partial oxidation methane reforming plant.

Approximately 50 percent of the total coal supply is used in pulverized fuel boilers for electric power generation and steam production.

3.3 Coal Gasification

The Lurgi gasifiers used in the Sasol I plant are slow moving bed, water-cooled reactors operating at approximately 2.5 MPa (25 atmospheres) with a gasification zone temperature of 1255K (1800°F).

The coal enters the following zones from top to bottom in the gasifier: preheat and devolatilization, gasification, combustion, and ash zone.

In the Lurgi process, the coal enters the pressurized reactor through a coal lock. The coal is then gasified with a counter-current flow of steam and oxygen. For each type of coal, the temperature and steam to oxygen ratio are varied to ensure complete gasification below the ash melting point.

The ash zone consists of a revolving ash grate and lock from where the ash is discharged as a granular solid.

3.4 Gas Cooling

Raw synthesis gas streams from a row of gasifiers are cooled by waste heat boilers and condensers. Low-pressure steam is generated by waste heat recovery.

During this cooling stage, an aqueous immiscible mixture, gas liquor, is condensed. In addition, product gas is cooled by heat exchange with cooling feed water. The purpose of this section is to cool the crude gasifier gas prior to gas purification in a Rectisol unit.

3.5 Gas Purification

Cooled raw gas discharged from the waste heat boilers and condensers still contains impurities, including carbon dioxide (CO_2), hydrogen sulfide H_2S), and hydrocarbons higher than methane. To purify the gas, cold methanol is used in the Rectisol unit. The Rectisol unit is designed to produce a purified gas containing less than 1.5% CO_2 and 0.1 ppm H_2S.

This process uses three methanol wash zones (prewash, mainwash, and finewash). Each zone successively purifies the gas to lower sulfur compound concentrations.

A mixture of methanol, naphtha, and H_2O is removed from the bottom of the absorber. Methanol is recovered by flashing in several stages. Naphtha is routed to the hydrogenation unit for further processing. Water effluent is sent to the tar and oil separation unit for hydrocarbon recovery and then to the Phenosolvan unit for recovery of phenol and NH_3 and removal of H_2S and other impurities prior to final processing in the wastewater treatment unit.

3.6 Tar and Oil Separation

The tar and oil separation unit receives the condensed gas liquor from the gasification gas cooling section and condensate from the Rectisol unit for separation into oil, tar and gas liquor, and naphtha.

A series of fractional distillation units is used in the tar and oil distillation unit to separate heavy tar, light tar, medium and heavy oils, and naphtha.

The naphtha is hydrodesulfurized for sulfur removal. The other streams are processed further or used as blending stocks for various end products.

The gas liquor is sent to the Phenosolvan unit to recover phenols and and NH_3 and remove H_2S. Major waste streams consist of a sludge made up of a mixture of heavy tar and dust, gases released from the depressurization vessels, and vent gases from atmospheric pressure surge tanks.

3.7 Phenosolvan

The aqueous liquor stream from the tar/oil separation unit is sent to the Phenosolvan unit where it is treated by solvent extraction with butyl acetate to recover phenol. Steam stripping removes CO_2, H_2S, and other volatile contaminants such as HCN, benzene, pyridine, and small quantities of phenol. The ammonia is then recovered by additional stripping with steam and converted to ammonium sulfate for sale as fertilizer.

The stripped liquor (Phenosolvan wastewater) has the composition shown as Stream 23 in Table 2. This stream is biologically treated prior to release or reuse in the plant as part of Sasol's overall water management plan.

3.8 Sulfur Recovery Unit

The acid gas streams (containing $CO_2$and H_2S) from the Rectisol unit are routed to the sulfur recovery unit.

The gas is sent through an absorption column where it is contacted with a countercurrent flow of proprietary absorber solution. The H_2S is absorbed and the solution is sent to an oxidizer where air causes the sulfide to be oxidized to sulfur which then floats to the surface for subsequent recovery.

A small liquid purge of absorber solution having the composition shown under Stream 21, Table 2, is required to prevent a build up of impurities. This represents the purge from a typical Stretford solution, but currently another proprietary solution is in use.

4.0 PREPARED COAL ANALYSIS (Phase I)

Table 3 shows the ultimate analysis and values for trace elements in prepared coal (Stream 16) and ash (Stream 17).

The laboratory results on Ni and Mn in the ash are approximately one-third higher than possible from the measured amount of these elements in the coal. These data and other irregular results reported in the literature reflect difficulties in sampling and analysis methods. These generally make an accurate trace element disposition hard to measure.

5.0 GASIFIER EMISSIONS (Phase I)

5.1 Start-up Vent gas

During a normal cold gasifier start-up with air, flue gas is vented at a rate of 1000 to 2000 Nm^3/hr for a period of 8 hours. A subsequent period of operation with oxygen results in a venting rate of 10,000 Nm^3/hr for 1 1/2 hours. The total flue gas vented approaches 31,000 Nm^3 at the raw gas composition shown in Table 1 plus nitrogen. At Sasol I, each gasifier undergoes a cold start-up two or three times per year resulting in a total of approximately 70 cold gasifier start-ups per year.

Also, a total of 70 start-ups per year will occur with gasifiers that are already warm. Vent gases for each warm gasifier start-up amount to 19,000 Nm^3 and have a composition nominally equivalent to raw gasifier gas.

5.2 Coal Lock Vent Gas

When a coal lock is depressurized, raw gas is vented. Approximately 98 percent of this gas is collected in a gas holder for use as fuel in the power plant steam superheater. Since many gasifiers are at various stages of the depressurizing-loading-repressurizing-unloading cycle of this process, uneven sequencing results in alternating excesses and shortages of coal lock vent gas with respect to the fuel demands of the superheater. These excesses are flared and normally average 50-350 Nm^3/hr (0.6 to 4 percent of total coal lock gas).

5.3 Raw Gas from Safety Valves

Raw gas releases through the safety valves are extremely rare, but emergency relief quantities of up to 50,000 Nm^3/hr per gasifier can be released into the atmosphere.

5.4 Superheater Flue Gases

The steam superheaters are fueled by raw gas and coal lock gas resulting in a flue gas consisting of approximately 20% CO_2 and

small quantities of CO, NO_x, SO_x, and other contaminants with the remainder being N_2, O_2, and H_2O. Since this type of equipment is commonly used in the utility industry, additional information will not be presented in this report.

6.0 ACID GASES FROM RECTISOL (Phase I)

6.1 High Pressure (HP) CO_2 Expansion Gas to Flare

The HP CO_2 expansion gas has the composition as shown in Table 1, Stream 8.

6.2 Acid Gases to Sulfur Recovery Unit

The major portion of acid gases from Rectisol including Low Pressure (LP) CO_2 expansion gas is routed to the sulfur recovery unit for H_2S removal and sulfur recovery. The composition of these gases is shown under Stream 9 in Table 1.

7.0 DEPRESSURIZATION GAS FROM TAR SEPARATOR (Phase I)

Small quantities of gas are continuously emitted from the tar separators, atmospheric drum, sludge sump, and tar storage tanks. These gases consist mostly of air, CO_2, H_2, CO, and CH_4 with small quantities of NH_3 and H_2S. Emissions have been greatly reduced in recent years by cooling the gas liquor prior to expansion in the tar separation unit.

7.1 Separator "A" and "B" Gases

Table 1 shows compositions of these streams based on three samples.

7.2 Oil Separator Vent Gases

Table 1 shows compositions of these streams based on two samples.

7.3 Gas Liquor Expansion Gas

Data were not made available on this stream and, therefore, are estimated in Phase II.

8.0 PHENOSOLVAN WASTEWATER (Phase I)

After phenol recovery, hydrocarbon extraction, ammonia recovery, and H_2S stripping, water effluent from the Phenosolvan unit requires additional treatment prior to release or reuse. The composition of Stream 23 is shown in Table 2.

9.0 SULFUR RECOVERY UNIT DISCHARGE (Phase I)

9.1 Tail Gas H_2S Content

The sulfur recovery unit was expected to have a tail gas H_2S concentration of 50-100 ppmv. Actual plant data have ranged from 0.008 to 0.074

vol. % (80 to 740 ppmv) as shown for Stream 20 in Table 1. A practical limit of less than 100 ppmv should be achievable at stable conditions in a well operated absorber.

9.2 Liquid Purge

A small purge is required to prevent the buildup of impurities. Side reactions result in the formation of a small amount of sodium carbonate, sodium thiosulfate, and sodium sulfate. Significant components of this stream are shown in the composition of Stream 21 in Table 2.

10.0 TRACE ELEMENTS IN TAR AND OIL (Phase I)

Quantities of trace elements present in tar and oil, obtained by mass spectrometer, are shown for Streams 12 and 13 in Table 2.

11. TRACE ELEMENTS IN PREPARED COAL AND DRY ASH (Phase I)

Quantities of trace elements present in coal and ash, obtained by mass spectrometer, are shown for Streams 16 and 17 in Table 3.

12.0 RESULTS AND DISCUSSIONS (Phase I)

12.1 Material Balance

Development of Material Balance

The commercial plant data provided by Sasol did not contain sufficient information to complete an overall material balance for the Lurgi coal gasification facility. Information from various sources was used as guidelines to estimate ranges of composition and quantities for the process streams associated with Lurgi gasification and gas and liquid treatment units.

The sources listed in the bibliography, including published information and nonproprietary studies, were used to establish an initial overall material balance for each individual process unit. After selected component balances confirmed that a material balance was reasonable for a particular process unit, this same procedure was repeated for each remaining downstream unit.

Upon completion of all individual unit balances, the overall gasification facility balance was calculated. Only a minor adjustment to several of the estimated streams was required to complete the overall balance.

Initial attempts to complete a material balance for the Rectisol unit were unsuccessful, based on the plant data furnished by Sasol and contained in Phase I. The total quantity of High Pressure and Low Pressure CO_2 vent gas and acid gas from Rectisol was reported as 150,000 Nm^3/hr, but individual quantities were not provided. A successful material balance was completed based on the assumptions that the acid gas and Low Pressure CO_2 vent gas are combined and

have a total flow of 142,500 Nm^3/hr. These gases are sent to the sulfur recovery unit. It is also assumed that the High Pressure CO_2 vent gas, with a flow of 7,500 Nm^3/hr, has a sufficiently high heating value and relatively low sulfur content to be suitable for use as fuel in the incincinerator or flare.

Since compositions and flow rates were not provided for various intermediate and product streams, attempts were made to obtain a general agreement between the published data sources. A consensus among these sources, however, was not usually achieved because the compositions and flow rates of the streams often varied significantly depending on feed coal composition and plant operating conditions. Therefore, only the published data considered to be similar to the Sasol I operating data were selected as a basis for material balance calculations.

Material Balance Accuracy

Ideally, complete operating data obtained under supervised test run conditions would ensure that the material balance is reasonable and accurate. For this report, however, engineering calculations and estimates were required to determine the flow rates for two of the three input streams to the coal gasification facility and for eleven of twenty output streams.

Despite the relatively large number of estimates required to complete the material balance, it is believed that this information is reasonably representative of a Sasol I type gasification operation. A calculated material balance such as this should not be used for process design purposes, detailed cost estimates, or environmental control requirements without first obtaining confirming test run data.

12.2 Sulfur Balance and Distribution

Development of Sulfur Balance

The Sasol I plant data did not contain sufficient information to complete a sulfur balance for the Lurgi coal gasification facility. The same sources of information used to calculate the overall material balance also served as guidelines for completing the sulfur balance.

Completion of the sulfur balance required the adjustment of the Sasol I coal feed sulfur content, an assumed order of magnitude sulfur level in the ash, and the estimation of the sulfur content of other pertinent streams. Published data sources were used to verify the reasonableness of the sulfur content estimates.

In particular, the estimated value of the 0.55 weight percent coal feed sulfur content selected for sulfur balance calculations is comparable to the 0.4 weight percent value for Sasol I coal given in Reference 6. This estimated value is within the composition range (assumed) of 0.5 to 1.5 percent as indicated by the average one percent sulfur content presented in the Sasol I operating data.

Sulfur Balance Accuracy

Since the sulfur balance is based on flow quantities established in the overall material balance, it is subject to any inaccuracies that may result from the calculations and estimates used in place of plant operating data for completion of the overall balance. However, the sulfur balance and sulfur distribution are within the normal operating ranges presented in the published data.

Although this information is reasonably representative of a Sasol I type operation, this balance should not be used for process design purposes, detailed cost estimates, or environmental control requirements unless it is used in conjunction with confirming test run data.

Sulfur Distribution

The Sasol I sulfur distribution presented in Figure 3 relates the sulfur content of each stream to the total sulfur content of the feed coal. For example, more than 89 percent of the sulfur contained in the feed coal becomes part of the gasifier gas while approximately 7 percent of the sulfur remains in the ash. About 4 percent of the total sulfur is contained in the liquid streams. The clean gas from the Rectisol unit contains essentially no sulfur.

Approximately 82 percent of the feed coal sulfur is recovered in the sulfur recovery unit as product sulfur. Another 4 percent of the total sulfur is contained in the naphtha, oils, and Phenosolvan wastewater and is recovered in other portions of the facility.

The sulfur recovery unit recovers approximately 99 percent of the H_2S contained in the Rectisol unit acid gas as sulfur product. However, sulfur compounds such as COS and CS_2 do not react with the absorbent resulting in an overall sulfur recovery of the unit actually being about 95 percent in this application.

12.3 Hydrocarbon Emissions

The atmospheric vent streams at the Sasol I coal gasification facility represent process sources of hydrocarbon emissions. These streams include the coal lock gas from the Lurgi gasifiers; vent gases from Separator "A", Separator "B", and the Oil Separator in the Tar and Oil Separation unit; gas liquor expansion gas; Rectisol High Pressure CO_2 vent gas; and Phenosolvan off gas.

Hydrocarbon emissions are minimized, however, by the process design for the facility. For example, about 98 percent of the coal lock gas is normally recovered and

utilized as fuel at the superheater. Although the remainder of the lock gas is vented to the atmosphere, it contains only one percent non-methane hydrocarbons. The High Pressure CO_2 vent gas contains only two percent non-methane hydrocarbons while the vent gases from the Tar and Oil Separation unit contain none. The High Pressure CO_2 vent gas is usually sent to fuel or the flare for an assumed 100 percent control of hydrocarbons in this stream, prior to release to atmosphere. Phenosolvan off gases are primarily CO_2 and contain no hydrocarbons. Although a complete analysis was not furnished by Sasol for this stream and an H_2S content was the only value estimated, data from other designs and sources indicate a CO_2 content exceeding 90 percent for this stream.

An undetermined amount of hydrocarbons from the Stretford unit is released to the atmosphere. This stream will normally be incinerated in U. S. plant designs.

12.4 Trace Elements Balance and Distribution

The Sasol I plant furnished for selected trace elements contained in their coal feed and gasifier products are similar to other data of this nature; e.g., the Kosovo data shown in Table 9. However, the raw data indicate the presence of either insufficient or excessive quantities of trace elements necessary to close the balance. This discrepancy results from the difficulty of obtaining representative samples of feed and products comparable both from a composition and time sequence of operation standpoint and analytical problems. Therefore, trace element data shown in Table 9 for Sasol I, Kosovo, and Sasol 1974 were adjusted to a closed balance for comparison purposes. Based on this adjustment an estimated trace metals distribution at closed balance condition for the Sasol I data is listed in Table 9 for Sb, As, Pb, Cd, Ni, Be, Hg, and Mn.

Antimony (Sb)

Approximately 90 percent of the antimony is contained in the ash with the remainder going to tar and oil. None is contained in the water phase. This distribution is expected since the metal and its oxide do not volatilize at gasifier temperatures and are insoluble in water.

Arsenic (As)

About a third of the arsenic is recovered in the ash while over half is contained in the water phase. These results are not unexpected due to the relatively low boiling and sublimation temperatures and relatively high solubilities of its oxides in water.

Lead (Pb)

Most of this metal and its compounds (89 percent) will be contained in the ash due to high boiling points. The remaining 8 percent of the lead is contained in the tar and is probably in the form of

decomposition products and carry-over. The low solubility of lead prevents any significant quantities from being present in the water phase.

Cadmium (Cd)

Since cadmium boils at 1040K (1413°F) and CdO decomposes at 1173 to 1273K (1652°F to 1832°F), it is reasonable that a large percent of the total cadmium is present in the ash. However, it is difficult to explain why 33 percent of the cadmium appears in the water phase since both Cd and CdO are insoluble. The presence of ammonia water and ammonium salts in the gas cooling operation are thought to account for an increased solubility and presence of CdO in the water phase.

Nickel (Ni)

Most of the nickel and its oxide (about 96 percent) are distributed to the ash due to their high boiling point and insolubility in water.

Beryllium (Be)

This extremely high boiling metal almost exclusively (99 percent) is retained in the ash.

Mercury (Hg)

The water phase is expected to contain a significant amount of the total mercury since mercury and its oxide have low boiling and decomposition temperatures in addition to their water solubility.

However, the estimated distribution for mercury shown in Table 9, as well as future test run data, will probably be the least accurate for the trace elements discussed in this report, due to the difficulty in obtaining a coal sample representative of large tonnage feed and the extremely low mercury content in this coal (<0.1ppm).

Manganese (Mn)

The high boiling point and low water solubility accurately predict that 99 percent of this metal is contained in the ash.

In summary, the Sasol I data indicate that most of these trace metals remain in the ash except for those with a low boiling point and high solubility, such as arsenic or mercury. The fact that a higher proportion of cadmium is distributed to the water phase possibly results from the presence of ammonium salts improving solubility. Since most of the trace metals end up in the ash, control efforts might emphasize resolving the problem of ash disposal in a manner designed to prevent leaching of these trace elements to the ground water.

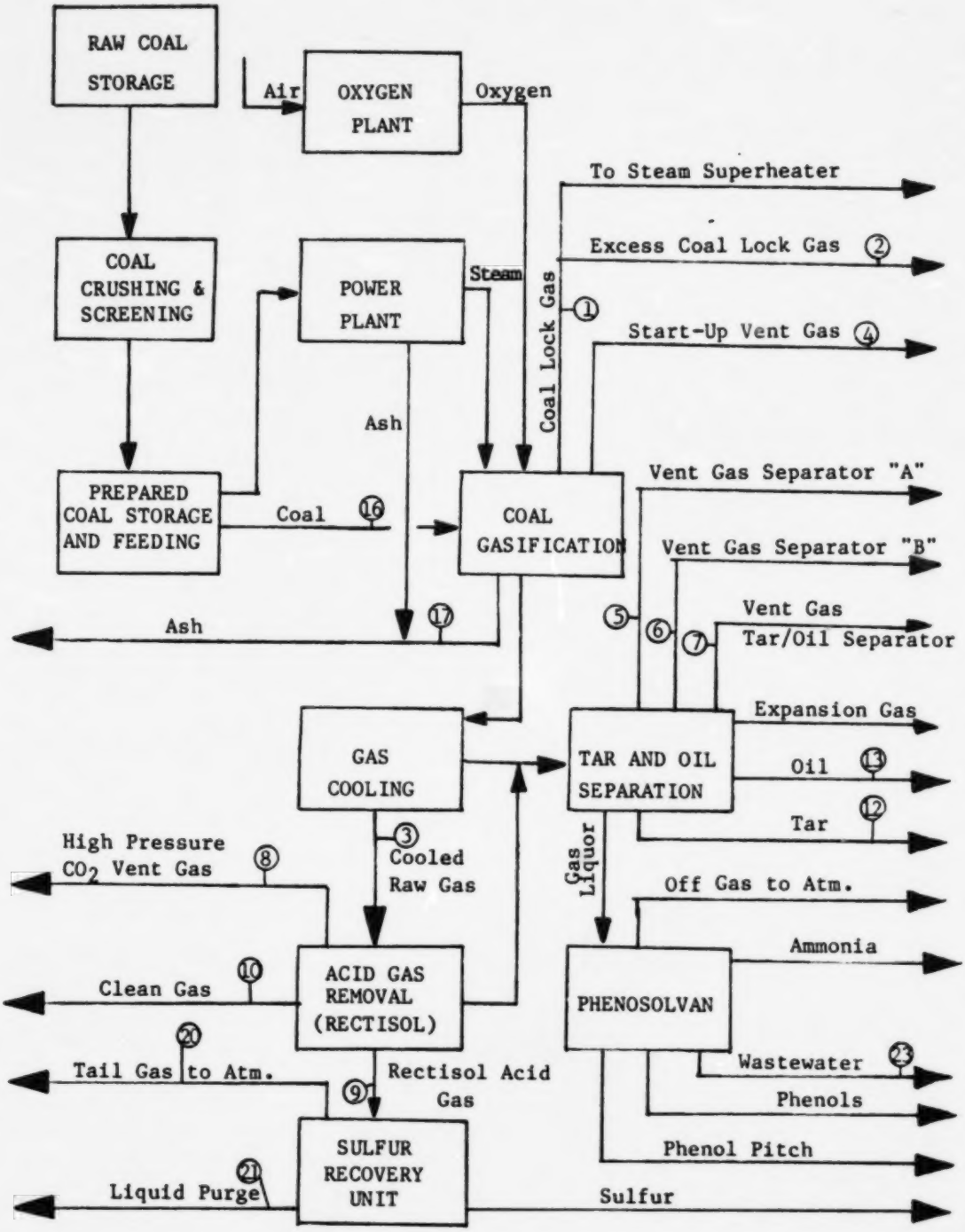


Figure 1. Block flow diagram of Sasol I gasification plant streams of major environmental interest (Phase I)

TABLE 1. SASOL I PLANT DATA - GAS STREAMS

COMPONENT		Stream number[a]/Identification 1-4 GASIFIER GAS[b]	5 SEPARATOR "A" VENT GASES	6 Separator "B" VENT GASES	7 GAS OIL SEPARATOR VENT GASES	8 HIGH PRESSURE CO_2 VENT GAS[c]	9 ACID GASES FROM RECTISOL[d]		10 CLEAN GAS	20 SULFUR RECOVERY UNIT TAIL GAS	PSVs RARE EMERGENCY RELIEFS
CO_2	Vol. %	27.93	7.0 - 18.1 %	4.7 - 11.8	75.1 -92.8	41.75	79.18	95.85	-	-	-
CO	Vol. %	20.66	1.6 - 7.1	1.6 - 2.8	0.6 - 2.0	22.37	7.62	0.43	-	-	-
H_2	Vol. %	40.32	2.9 - 13.9	3.0 - 5.4	1.6 - 4.0	20.72	1.77	0.06	-	-	-
CH_4	Vol. %	9.05	0.7 - 3.2	0.6 - 1.3	0.3 - 1.0	13.00	9.28	0.89	-	-	-
C_2H_4	Vol. %	0.08	-	-	-	0.11	0.19	0.19	-	-	-
C_2H_6	Vol. %	0.18	-	-	-	0.52	0.91	0.66	-	-	-
C_3H_6	Vol. %	0.06	-	-	-	0.03	0.05	0.10	-	-	-
C_3H_8	Vol. %	0.04	-	-	-	0.04	0.07	0.09	-	-	-
C_4H_8	Vol. %	0.09	-	-	-	0.03	0.04	0.07	-	-	-
C_4H_{10}	Vol. %	0.06	-	-	-	0.02	0.03	0.10	-	-	-
C_5H_{12}	Vol. %	0.05	-	-	-	0.02	0.04	0.04	-	-	-
C_6H_6	Vol. %	0.04	-	-	-	0.11	0.02	0.02	-	-	-
C_7H_8	Vol. %	0.04	-	-	-	0.02	0.01	0.01	-	-	-
CH_3OH	Vol. %	0.36	-	-	-	0.04	0.06	0.04	-	-	-
N_2 + Ar	Vol. %	0.74	45.2- 68.9	61.8 - 71.1	2.6 -13.5	1.00	0.27	0.53	-	-	-
O_2	Vol. %	-	12.0 - 18.3	16.4 - 18.9	0.7 - 3.6	-	-		-	-	-
H_2S	Vol. %	0.30	-	-	-	0.22	0.46	0.92	-	.008 - .074	-
COS	ppmv	-	-	-	-	-	-	170	-	-	-
CS_2	ppmv	-	-	-	-	-	-	<1	-	-	-
RSH	ppmv	-	-	-	-	-	-	120	-	-	-
C_4H_4S	ppmv	-	-	-	-	-	-	<1	-	-	-
CN^-	ppmv	-	-	-	-	-	-	6	-	-	-
NO	ppmv	-	-	-	-	-	-	<0.01	-	-	-
NH_3	ppmv	-	-	-	-	-	-	4	-	-	-
NH_3	g/Nm^3	-	1.77- 3.95	2.29- 2.94	0.84- 7.49	-	-	-	-	-	-
H_2S	g/Nm^3	-	0.32- 5.43	0.33- 7.39	11.43-13.94	-	-	-	-	-	-
H_2O		SAT.	-	-	-	-	-	-	-	-	-
RATE, Nm^3/hr		e, f, g, h	<10	<10	<10	150,000 total			-	-	Up to 50,000

[a] See Figure 1

[b] Gas composition essentially the same for : Stream 1 - TOTAL COAL LOCK GAS
Stream 2 - EXCESS COAL LOCK GAS
Stream 3 - COOLED RAW GAS
Stream 4 - START-UP VENT GAS

[c] Non-Selective Rectisol

[d] Includes LP CO_2 Rectisol Off Gas at Composition Listed in First Column of Figures. The two columns represent two different streams at two compositions which are later combined and sent to sulfur recovery unit.

[e] 8000 Nm^3/hr for TOTAL COAL LOCK GAS

[f] 50-350 Nm^3/hr for EXCESS COAL LOCK GAS

[g] Approx. 500,000 Nm^3/hr for COOLED RAW GAS

[h] 31,000 Nm^3/hr for cold START-UP VENT GAS, 70 Times/Year
19,000Nm^3 for warm START-UP VENT GAS, 70 Times/Year

TABLE 2. SASOL I PLANT DATA - LIQUID EFFLUENTS

COMPONENTS		Stream Number[a]/Identification 12 WASTE TAR FROM SEPARATOR PLANT	13 WASTE OIL FROM SEPARATOR PLANT	21 LIQUID PURGE FROM SULFUR RECOVERY UNIT[b]	23 WASTEWATER FROM PHENOSOLVAN
NH_4^+	mg/l	-	-	-	125
CN^-	mg/l	-	-	-	0.05
CNS^-	mg/l	-	-	-	40
S^-	mg/l	-	-	-	2
F^-	mg/l	-	-	-	50
Cl^-	mg/l	-	-	-	20
COD	mg/l	-	-	-	1190
TOC	mg/l	-	-	-	400
TSS	mg/l	-	-	-	8
Phenols	mg/l	-	-	-	150
Vanadium	g/l	-	-	0.7	-
ADA	g/l	-	-	1.6	-
Thiosulphate	g/l	-	-	30	-
pH		-	-	-	8.6
Sb	ppm	0.9	0.5	-	-
As	ppm	4.1	26	-	-
Pb	ppm	50	0.7	-	-
Cd	ppm	0.04	0.3	-	-
Ni	ppm	2.7	1.2	-	-
Be	ppm	0.8	0.05	-	-
Hg	ppm	0.4	0.01	-	-
Mn	ppm	2.7	0.03	-	-
Rate Mg/hr		0.5	0.05	-	430

[a] See Figure 1

[b] Based on Stretford solution. Recent data indicate another absorber liquid is currently in use.

TABLE 3. SASOL I PLANT DATA - SOLIDS

COMPONENT		Stream Number[a]/Identification 16 PREPARED COAL	17 DRY ASH
C	Wt.%	47	-
H	Wt.%	3	-
N	Wt.%	1	-
O	Wt.%	10	-
S	Wt.%	1	-
Ash	Wt.%	32	-
Moisture	Wt.%	9	-
Sb	ppm	< 0.05	< 0.05
As	ppm	3	2
Pb	ppm	15	50
Cd	ppm	< 0.1	< 0.1
Ni	ppm	40	180
Be	ppm	2	< 0.04
Hg	ppm	< 0.1	< 0.1
Mn	ppm	500	2000
Coal to Power Station	Mg/hr	315	-
Coal to Gasification	Mg/hr	385	-
Power Station Ash	Mg/hr	-	100
Gasification Ash	Mg/hr	-	120

[a] See Figure 1

[b] Raw data as reported by Sasol

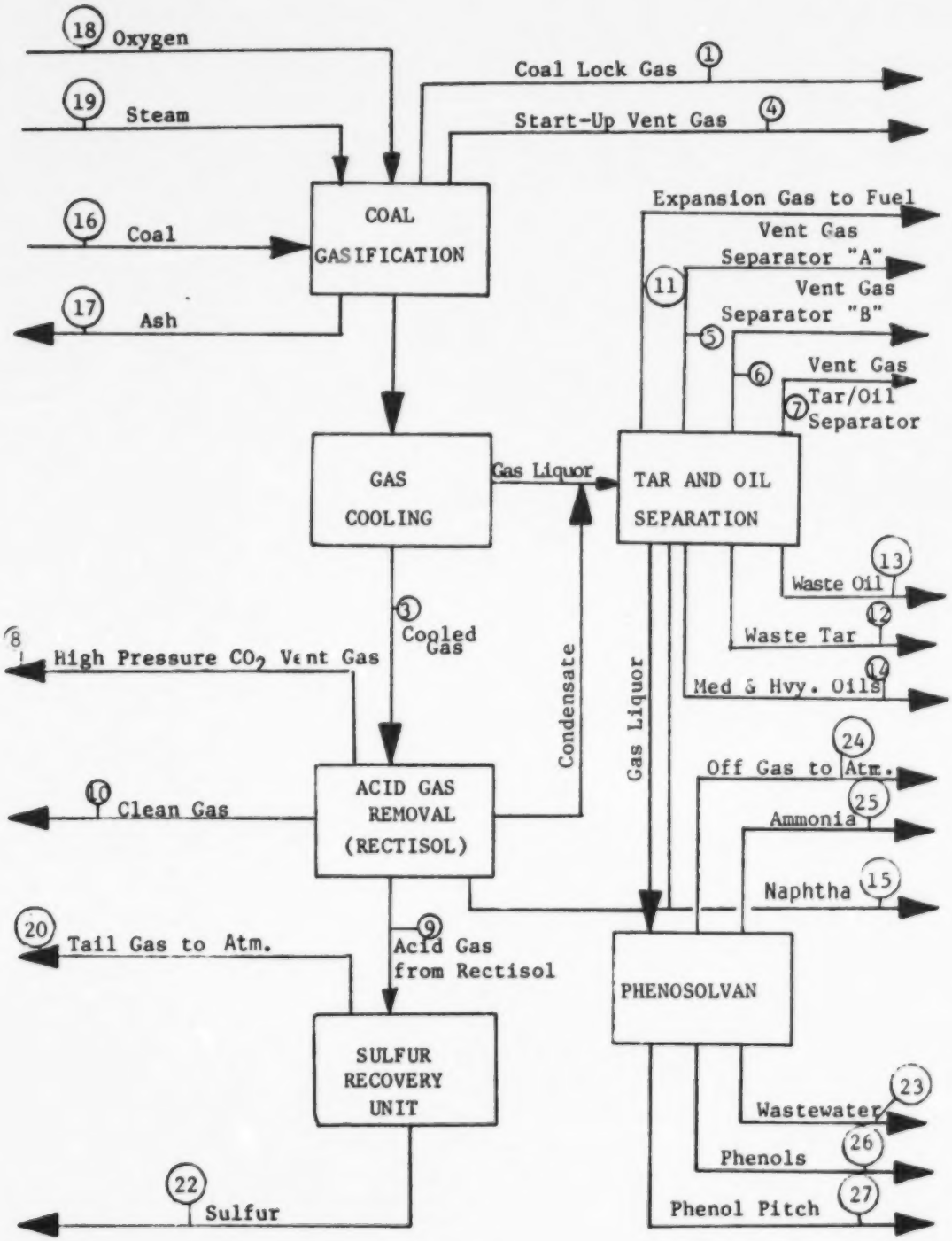


Figure 2. Block flow diagram of Sasol I gasification plant streams of major environmental interest (Phase II)

TABLE 4. SASOL PLANT AND ESTIMATED DATA - GAS STREAMS (a)

COMPONENTS		Stream Number[b]/Identification 1 TOTAL COAL LOCK GAS	4 START-UP VENT GAS	5 SEPARATOR "A" VENT GAS	6 SEPARATOR "B" VENT GAS	7 GAS OIL SEPARATOR VENT GAS	8 HIGH PRESSURE VENT GAS TO FUEL[d]	9 ACID GASES FROM RECTISOL	10 CLEAN GAS FROM RECTISOL	11 GAS LIQUOR EXPANSION GAS	20 SULFUR RECOVERY UNIT TAIL GAS	24 OFF GAS FROM PHENO-SOLVAN
CO_2	Vol.%	27.93	27.93	11.21	8.48	83.87	41.75	93.20[e]	0.5[f]	83.87	-	-
CO	Vol.%	20.66	20.66	4.22	2.28	0.61	22.37	1.57	-	0.61	-	-
H_2	Vol.%	40.32	40.32	8.00	4.18	1.33	20.72	0.33	-	1.33	-	-
CH_4	Vol.%	9.05	9.05	1.84	0.95	2.55	13.00	2.21	-	2.55	-	-
C_2H_4	Vol.%	0.08	0.08	-	-	-	0.11	0.19	-	-	-	-
C_2H_6	Vol.%	0.18	0.18	-	-	-	0.52	0.70	-	-	-	-
C_3H_6	Vol.%	0.06	0.06	-	-	-	0.03	0.09	-	-	-	-
C_3H_8	Vol.%	0.04	0.04	-	-	-	0.04	0.09	-	-	-	-
C_4H_8	Vol.%	0.09	0.09	-	-	-	0.03	0.06	-	-	-	-
C_4H_{10}	Vol.%	0.06	0.06	-	-	-	0.02	0.09	-	-	-	-
C_5H_{12}	Vol.%	0.05	0.05	-	-	-	0.02	0.04	-	-	-	-
C_6H_6	Vol.%	0.04	0.04	-	-	-	0.11	0.02	-	-	-	-
C_7H_8	Vol.%	0.04	0.04	-	-	-	0.02	0.01	-	-	-	-
CH_3OH	Vol.%	0.36	0.36	-	-	-	0.04	0.04	-	-	-	-
N_2 + Ar	Vol.%	0.74	0.74	58.64	66.02	8.11	1.00	0.48	-	8.11	-	-
O_2	Vol.%	-	-	15.60	17.55	2.16	-	-	-	2.16	-	-
H_2S	Vol.%	0.30	0.30	0.14	0.20	0.83	0.22	0.86	<0.00001[f]	0.83	0.01	1.0
COS	ppmv	-	-	-	-	-	-	140	-	-	139	-
CS_2	ppmv	-	-	-	-	-	-	<1	-	-	<1	-
RSH	ppmv	-	-	-	-	-	-	100	-	-	99	-
C_4H_4S	ppmv	-	-	-	-	-	-	<1	-	-	<1	-
CN	ppmv	-	-	-	-	-	-	5	-	-	5	-
NO	ppmv	-	-	-	-	-	-	<.01	-	-	<0.01	-
NH_3	ppmv	-	-	-	-	-	-	3	-	-	3	-
NH_3	g/Nm^3	-	-	2.73	2.58	4.17	-	-	-	4.17	-	-
H_2S	g/Nm^3	-	-	2.16	2.99	12.72	-	-	-	12.72	-	-
H_2O		SAT	-	-	-	-	-	-	-	-	-	-
RATE Nm^3/hr		8,000[f]	400[f]	10[f]	10[f]	10[f]	7,500	142,500	364,200	-	-	-
RATE lb/hr		16,912	831	31	32	41	19,225	599,641	461,722	1,025	595,585	9,500
RATE kg/hr		7,671	377	14	15	19	8,700	271,993	209,435	465	270,151	4,309

a All values not indicated by c, d, or f are calculated or engineering estimates.

b See Figure 2

c Data furnished by Sasol, for composition and Nm^3 only

d Data furnished by Sasol, for composition only

e Recent Sasol review indicated CO_2 vol% is usually higher than this.

f Data furnished by Sasol.

TABLE 5. SASOL I PLANT AND ESTIMATED DATA - LIQUID EFFLUENTS[a]

COMPONENTS		Stream Number[b]/Identification 12 WASTE TAR FROM SEP. PLANT	13 WASTE OIL FROM SEP. PLANT	14 MEDIUM AND HEAVY OILS	15 NAPHTHA FROM RECTI-SOL	23 WASTEWATER FROM PHENOSOL-VAN	26 CRUDE PHENOLS	27 PHENOL PITCH
NG^+	mg/l	-	-	-	-	125 [c]	-	-
CN^-	mg/l	-	-	-	-	0.05[c]	-	-
CNS^-	mg/l	-	-	-	-	40 [c]	-	-
S^-	mg/l	-	-	-	-	2 [c]	-	-
F^-	mg/l	-	-	-	-	50 [c]	-	-
Cl^-	mg/l	-	-	-	-	20 [c]	-	-
COD	mg/l	-	-	-	-	1190 [c]	-	-
TOC	mg/l	-	-	-	-	400 [c]	-	-
TSS	mg/l	-	-	-	-	8 [c]	-	-
Phenols	mg/l	-	-	-	-	150 [c]	-	-
H_2S	wt. %	-	-	-	0.02	-	-	-
RSH	wt. %	-	-	-	0.88	-	-	-
pH		-	-	-	-	8.6[c]	-	-
Sb	ppm	0.9 [c]	0.5 [c]	-	-	-	-	-
As	ppm	4.1 [c]	26. [c]	-	-	-	-	-
Pb	ppm	50. [c]	0.7 [c]	-	-	-	-	-
Cd	ppm	0.04[c]	0.3 [c]	-	-	-	-	-
Ni	ppm	2.7 [c]	1.2 [c]	-	-	-	-	-
Be	ppm	0.8 [c]	0.05[c]	-	-	-	-	-
Hg	ppm	0.4 [c]	0.01[c]	-	-	-	-	-
Mn	ppm	2.7 [c]	0.03[c]	-	-	-	-	-
RATE Mg/hr		0.5 [c]	0.05[c]	9.07	4.54	430. [c]	1.81	0.23
RATE lb/hr		1102	110.	20,000	10,000	947,988	4000	500.
RATE kg/hr		500	50	9,072	4,536	430,000	1814	227

[a] All values not indicated by [c] are calculated or engineering estimates

[b] See Figure 2

[c] Data furnished by Sasol

TABLE 6. SASOL I PLANT AND ESTIMATED DATA - SOLIDS[a]

COMPONENTS		Stream Number[b]/Identification 16 COAL TO GASIFIER	17 GASIFIER ASH	22 SULFUR PRODUCT
C	wt.%	45.88	-	-
H	wt.%	2.88	-	-
N	wt.%	0.98	-	-
O	wt.%	9.75	-	-
S	wt.%	0.55	0.125	100.0
Ash	wt.%	31.21	-	-
Moisture	wt.%	8.75	(DRY)[c]	-
Sb	ppmw	0.05[c]	0.05[c]	-
As	ppmw	3 [c]	2 [c]	-
Pb	ppmw	15 [c]	50 [c]	-
Cd	ppmw	0.1[c]	0.1 [c]	-
Ni	ppmw	40 [c]	180 [c]	-
Be	ppmw	2 [c]	0.04[c]	-
Hg	ppmw	0.1[c]	0.1 [c]	-
Mn	ppmw	500 [c]	2000 [c]	-
RATE	Mg/hr	385	120	1.73
RATE	lb/hr	848,780	265,555	3,815
RATE	kg/hr	385,000	120,000	1,730

(a) All values not indicated by [c] are calculated or engineering estimates

(b) See Figure 2

(c) Data furnished by Sasol

TABLE 7. SASOL I OVERALL MATERIAL BALANCE [a]

INPUTS				OUTPUTS			
Stream No.[b]	Identification	Mass Flow Rate lb/hr	kg/hr	Stream No.[b]	Identification	Mass Flow Rate lb/hr	kg/hr
16	Coal to Gasification	848780	385000[c]	1	Total Coal Lock Gas	16912	7671[c]
18	Oxygen (96.4%) to Gasifiers	282500	128140	4	Start-Up Vent Gas (Avg)	831	377[c]
19	Steam to Gasification	1225000	555650	5	Separator "A" Vent Gas	31	14[c]
				6	Separator "B" Vent Gas	32	15[c]
				7	Gas Oil Separator, Vent Gas	41	19[c]
TOTAL		2356280	1068790	8	High Pressure CO_2 Vent Gas	19225	8720
				10	Clean Gas	456028	206852
				11	Gas Liquor Expansion Gas	1025	465
				12	Waste Tar	1102	500[c]
				13	Waste Oil	110	50[c]
				14	Medium and Heavy Oils	20000	9072
				15	Naptha	10000	4536
				17	Gasifier Ash	264555	120000[c]
				20	Sulfur Unit Tail Gas	595585	270151
				22	Sulfur from Sulfur Recovery Unit	3815	1730
				23	Phenosolvan Wastewater	947988	430000[c]
				24	Phenosolvan Off Gas	9500	4309
				25	Ammonia	5000	2268
				26	Crude Phenols	4000	1814
				27	Phenol Pitch	500	227
					TOTAL	2356280	1068790

[a] All values not indicated by [c] are calculated or engineering estimates

[b] See Figure 2

[c] Data furnished by Sasol

TABLE 8. SASOL I OVERALL SULFUR BALANCE (a)

INPUTS

Stream No.[b]	Identification	Mass Flow Rate lb/hr	Mass Flow Rate kg/hr	Wt. %, S.	Sulfur Flow Rate lb/hr	Sulfur Flow Rate kg/hr
16	Coal to Gasification	848780	385000	0.55	4668	2117

OUTPUTS

Stream No.[c]	Identification	Mass Flow Rate lb/hr	Mass Flow Rate kg/hr	Wt. %, S.	Sulfur Flow Rate lb/hr	Sulfur Flow Rate kg/hr
1	Total Coal Lock Gas	16912	7671	0.455[c]	77	35
4	Start-Up Vent Gas (Avg)	831	377	0.455[c]	4	2
8	High Pressure CO_2 Vent Gas	19225	8720	0.255[c]	49	22
10	Clean Gas	456028	206852	<0.00001[c]	NIL	NIL
11	Gas Liquor Expansion Gas	1025	465	0.80	8	4
14	Medium & Heavy Oils	20000	9072	0.30	60	27
15	Naphtha	10000	4536	0.90	90	41
17	Gasifier Ash	264555	120000	0.125	331	150
20	Sulfur Unit Tail Gas	595585	270151	0.0244	145	66
22	Sulfur	3815	1730	100.00	3815	1730
23	Phenosolvan Wastewater	947988	430000	0.0024	23	10
24	Phenosolvan Offgas	9500	4309	0.70	66	30
	TOTAL				4668	2117

a All values not indicated by [c] are engineering estimates

b See Figure 3

c Data furnished by Sasol

TABLE 9. TRACE ELEMENT BALANCE AND DISTRIBUTION

Component	% in Ash	% in Tar	% in Oil	% in Water	Remarks
Sb					
Sasol I Data	90.8	4.3	3.2	NR	Data: questionable analyses in coal and ash. <0.05 ppm in coal.
Kosovo (a)	15.9 (23.9)	1.21	TR	NR	79.4% short of closing balance.
Kosovo Adj	92.9	7.1	TR	NR	Adjusted total in coal to force balance.
1974 Sasol (b)	40	3	0.5	36	20% short
Sasol Adj	50	3.75	0.63	45	Adjusted total in coal to force balance.
N. Dakota (c)	100	0	0	0	Closed balance.
EST. BALANCE	90	6	4	0	Closed balance.
As					
Sasol I Data	20.8	0.19	0.11	67.7	11.2% short of closing balance.
Kosovo	20.2 (596)	0.17 (5.0)	NIL (0.3)	0.02 (4.1)	Percent in water calculated from effluent analysis (1974).
Kosovo Adj.	99.1 (98.5)	0.8 (0.8)	(TR)	0.1 (0.7)	Approx. 33% of arsenic was in drier condensate, 77.98% short.
1974 Sasol	36	2.5	5.2	90	Adjusted total in coal to force balance.
N. Dakota	90.8	3.2	4.3	1.7	33.7% excess.
EST. BALANCE	36	2.5	5.2	56.3	Closed balance
Pb					Closed balance
Sasol I Data	104.9	0.04	0.0005		4.945% excess
Kosovo	71.5 (412)	20.0		2.8	Analyses showed shortage & excess.
Kosovo Adj.	75.8 (94.8)	21.2 (4.6)		3.0 (0.6)	Adjusted total in coal to force balance
1974 Sasol	180	8.2	0.02	3.2	91.42% excess.
N. Dakota	14.5	4.5	1.6	79.4	Closed balance
EST. BALANCE	88.6	8.2	NIL	3.2	Closed balance.

(Continued)

TABLE 9 (Continued)

Component	% in Ash	% in Tar	% in Oil	% in Water	Remarks
Cd					
Sasol I Data	-	-	-	-	<0.1 ppm in coal.
Kosovo	48.4 (275)	5.8	TR	0.3	Excess and shortage.
Kosovo Adj.	88.8 (97.8)	10.6 (2.1)	TR	0.6 (0.1)	Adjusted total in coal to force balance.
1974 Sasol	40.0	0.5	1.1	35	23% short.
N. Dakota	14.5	4.5	1.6	79.4	Closed balance
EST. BALANCE	50.0	15.8	1.1	33.1	Closed balance (CdO soluble in NH4 salts).
Ni					
Sasol I Data	140	TR	TR	NR	40% excess.
Kosovo	124 (33.9)	0.1 (0.6)	TR	0.2 (0.3)	Excess and shortage.
Kosovo Adj	99.7 (97.4)	0.1 (1.7)	TR	0.2 (0.9)	Adjusted total in coal to force balance.
1974 Sasol	154	0.05	0.01	0.64	54.7% excess.
N. Dakota	93.3	5.7	0.7	0.3	Closed balance
EST. BALANCE	96	3	0.5	0.5	Closed balance
Be					
Sasol I Data	11.2	0.05	TR	TR	88.75% short
Kosovo	63.68	0.2	TR	TR	26.12% short
Kosovo Adj.	99.7	0.3	TR	TR	Adjusted total in coal to force balance.
1974 Sasol	1	0.5	0.1	1.6	93% short
N. Dakota	99.1	0.9	0	0	Closed balance
EST. BALANCE	99	1.0	0	0	Closed balance

(Continued)

TABLE 9 (Continued)

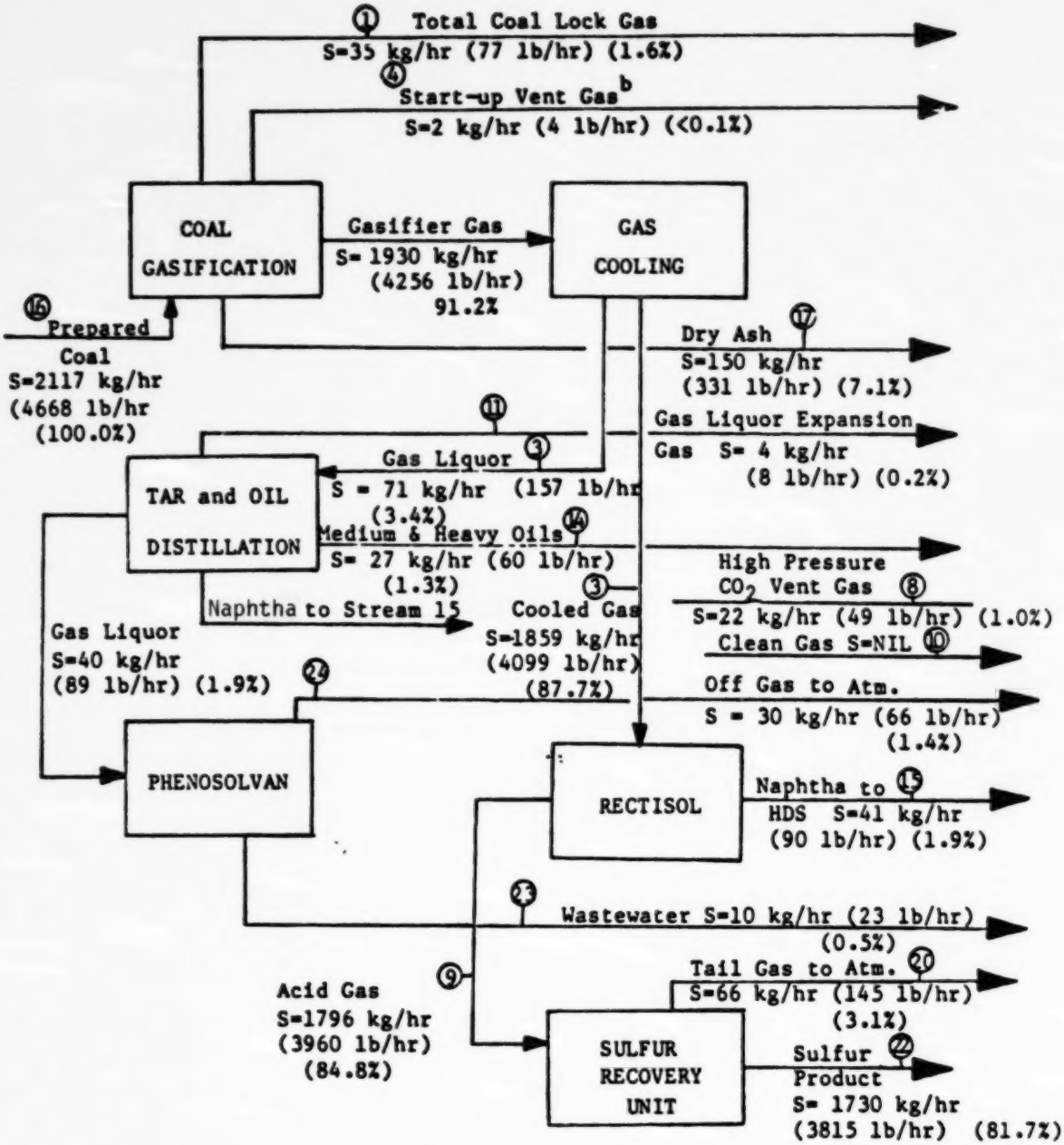
Component	% in Ash	% in Tar	% in Oil	% in Water	Remarks
Hg					
Sasol I Data	-	-	-	-	<0.1 ppm in Coal.
Kosovo	39.8	TR	TR	0.9	59.3% short.
Kosovo Adj.	97.8	TR	TR	2.2	Adjusted total in coal to force balance.
1974 Sasol	40	4.9	0.5	32	23% short.
N. Dakota	1.4	38.2	0.5	59.9	Closed balance.
EST. BALANCE	44	10.5	0.5	45	Closed balance
Mn					
Sasol I Data	124	TR	TR	NR	24% excess
Kosovo	186	NR	NR	NR	86% excess
Kosovo Adj.	100	NR	NR	TR	Adjusted total in coal to force balance.
1974 Sasol	154	TR	TR	0.36	54.36% excess.
N. Dakota	99.2	0.7	TR	0.1	Closed balance.
EST. BALANCE	99.2	0.7	TR	0.1	Closed balance.

Notes: Second analysis is shown in parentheses.

(a) References 1 and 2.

(b) Reference 3.

(c) References 4 and 5.



Notes:

[a] These values are primarily based on calculations and estimates.

[b] Average rate for start-up vent gas.

Figure 3. Sulfur balance and distribution for Sasol I gasification plant[a]

REFERENCES

1. Bombaugh, K.J., W.E. Corbett, and M.D. Matson (Radian) "Environmental Assessment: Source Test and Evaluation Report - Lurgi (Kosovo)" EPA-600/7-79-190, August 1979

2. Kosovo Gasification Plant Data Appendix for Phase II Ster, Review Copy Wayne S. Seames, June 1980

3. "Data Prepared for Visit of United States Environmental Protection Agency" November 1974 [Attachment to March 9, 1981, letter from T. Kelly Janes (EPA) to S.J. Thomson (Fluor)]

4. Final EIS "Great Plains Gasification Project" Vol 1 of 3 DOE EIS-0072F, August 1980

5. Hoede, K., G. Kasper, S.J. Thomson "Quantifizierung der Umweltbeeintrachtingung durch moderne Verfahren der Kohlevergasung and -verflussingung Umweltforschungsplan des BMI, "Bonn/Federal Republic of Germany, Luftreinhaltung, Forschungsbericht 10403348, January 1981

6. Anastai, J.L. (TRW) "Sasol: South Africa's Oil from Coal Story", EPA-600/8-80-002, January 1980

BIBLIOGRAPHY

1. Bombaugh, K. J., K. W. Lee, R. G. Oldham (Radian), and S. Kapor "Characterization of Process Liquids and Organic Condensates from the Lurgi Coal Gasification Plant at Kosovo, Yugoslavia", 1981

2. Ghassemi, M., K. Crawford, and S. Quinlivan "Environmental Assessment Data base for High-Btu Gasification Technology" Vol. II PB-288603 EPA-600/7-78-186b, September 1978

3. Krieb, K. H., and K. Heyn (Steag) "High-Pressure Coal Gasification Combined-Cycle Power Generation" In: Conference Proceedings: Synthetic Fuels - Status and Direction, Volume 2, EPRI WS-79-238, May 1981

4. Perry, R. H. and C. H. Chilton "Chemical Engineers' Handbook" Fifth Edition, 1973

5. Rudolph, P. F. N., C. Hafke, P. K. Herbert (Lurgi GMBH) "Lurgi Coal Gasification" In: Conference Proceedings: Synthetic Fuels Status and Direction, Volume 2, EPRI WS-79-238, May 1981

6. Sharman, R.B., and J. E. Scott (British Gas Corporation) "The British Gas/Lurgi Slagging Gasifier and its Relevance to Power Generation: (Ibid)

7. Somerville, M. H. et al, "An Environmental Assessment of Proposed 250 MMSCFD Dry Ash Lurgi Coal Gasification Facility Located in Dunn County, North Dakota Volume VI, December 1976, University of North Dakota Bulletin #76-12-EES-OB"

8. "Lurgi-based Indirect Coal Liquefaction Evaluation, Proposed Final Report" December 1981 [Marked-up draft attached to February 10, 1982 letter from P. Naude (Sasol) to Emil Parente (Fluor)]